

QUANTITATIVE STUDIES ON MARINE
DIATOMS AND DINOFLAGELLATES
AT FOUR INSHORE STATIONS ON
THE COAST OF CALIFORNIA IN 1923

BY

HENRY P. DORMAN

AND

PELAGIC FISH EGGS OFF LA JOLLA,
CALIFORNIA

BY

P. S. BARNHART

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INTRODUCTION

The present paper concerns chiefly surface collections of diatoms and dinoflagellates made throughout the year 1923 at four inshore stations along the coast of California. These stations were at Hopkins Marine Laboratory at Pacific Grove and at Point Hueneme, Oceanside, and La Jolla piers, the last being the station at the Scripps Institution of Oceanography. In addition, this paper deals with bottom collections made at the La Jolla pier during the last sixteen weeks of the year. These latter were made at the same time as corresponding surface collections.

The chief purpose of the present paper is to add to the evidence on the surface distribution of diatoms and dinoflagellates with particular reference to: (1) quantitative distribution at different periods of the year; (2) quantitative distribution at different stations; (3)

quantitative distribution of genera and species at a given station; (4) comparison of quantitative distribution of prominent genera and species at certain periods of the year at the four stations; and (5) a consideration of temperatures and salinities, and their probable influence on the distribution of diatoms and dinoflagellates.

The author desires to express thanks to Esther N. Dorman for assistance in calculations and in tracing curves necessary for proper illustration.

STATIONS

Three of the four stations at which collections were made in 1923 have been used regularly by this institution for at least the last three years. These stations are Point Hueneme, Oceanside, and La Jolla piers. Collections of diatoms and dinoflagellates at Pacific Grove for this series were made for the first time in 1923, and the results for this station are of interest, both from the point of view of location and method of collection. Methods of collection will be considered later.

Pacific Grove is the farthest north and La Jolla pier is the farthest south of the four stations. Their latitudes and longitudes are as follows:

	Pacific Grove	Point Hueneme	Oceanside	La Jolla
Latitude	36° 38' N	34° 9' N	33° 12' N	32° 52' N
Longitude	121° 56' W	119° 13' W	117° 22' W	117° 17' W

Calculations based on differences in latitude indicate that distances in nautical miles from station to station are as follows: Pacific Grove, 149—Point Hueneme, 57—Oceanside, 20—La Jolla. These differences are reflected in temperatures, as can be seen by consulting table 1 and figure 3. The lower temperatures appear northward.

Collections at Pacific Grove were made inshore by wading to about forty feet from the water's edge. Collections at the other three stations were made from the ends of the piers. Lengths from the shore and depths of water at the ends of the piers are as follows:

	Point Hueneme	Oceanside	La Jolla
Length (feet)	700	500	1000
Depth (feet)	15-22	12-20	15-22

METHODS OF COLLECTION AND STUDY

The methods of collection were those described by Allen (1921). Within the last year the method of preparation of samples for counting has been modified and is therefore described below.

Collections at the La Jolla pier usually were made at 7 A.M. The time of making collections at the other three stations varied, but they usually were made between 7 and 10 o'clock A.M.

Surface collections were made almost daily, except during the weeks for which no data are presented in table 1 and graphs 1, 2, 3, and 4. By inspection it is readily apparent that data for the entire year are complete for Point Hueneme and La Jolla piers, and incomplete only for four weeks for Oceanside pier. Data for fourteen weeks for Pacific Grove are lacking.

Surface collections were made by straining 25 liters of water through a net of No. 25 silk cloth, and preserving the concentrated plankton in 5 per cent formaldehyde. For collecting bottom samples at La Jolla pier, the Kofoed bucket, which holds 20 liters of water, was used; otherwise, procedure was exactly the same as for surface collections.

The method employed in the preparation of the sample and in counting reduces all data to weekly averages for each station. This method, including modifications of Allen's original method mentioned above, is as follows: From each day's catch at a given station (50 c.c. of concentrated plankton) 2 cubic centimeters are taken. These 2 cubic centimeter samples for a given week are mixed, and one-fourth of a sample of 1 cubic centimeter from the mixture is counted on the Sedgwick-Rafter counting slide. The daily catches of 50 cubic centimeters each are thoroughly agitated before the 2 cubic centimeter samples are withdrawn in a pipette, and the mixture of the 2 cubic centimeter samples from the daily catches likewise is thoroughly agitated in order to secure a fair sample for counting. After making calculations, which, of course, are based on the number of liters strained through the net, the number of cubic centimeters of concentrated plankton, and the fraction counted, the result is in weekly averages of numbers of diatoms and dinoflagellates per liter. Diatoms and dinoflagellates are entered separately in the count records.

TABLE 1—(Continued)

Week ending	Pacific Grove				Point Hueneme Pier				Oceanside Pier				La Jolla Pier			
	Diatoms	Dino-flagellates	Temp. in °C.	Sal. 0/00	Diatoms	Dino-flagellates	Temp. in °C.	Sal. 0/00	Diatoms	Dino-flagellates	Temp. in °C.	Sal. 0/00	Diatoms	Dino-flagellates	Temp. in °C.	Sal. 0/00
7	—1	1,200	48	12.95	33.73	25,664	17,600	12.56	33.79	1,408	864	33.69	3,296	1,280	19.90	33.75
	8	960	00	11.83	33.77	172,736	24,320	14.78	33.84	7,264	416	33.71	96	896	19.85	33.73
	15	2,560	00	12.11	33.73	1,600	1,856	17.00	33.77	4,768	320	33.74	144	688	20.74	33.76
	22	1,360	32	13.89	33.64	288,476	7,936	13.44	33.74	608	800	33.71	320	416	20.55	33.71
8	29	1,072	112	13.00	33.81	158,080	1,984	16.39	33.76	736	288	33.76	16	368	21.11	33.73
	—5	1,104	32	12.11	33.80	29,376	3,680	15.56	33.76	1,920	416	33.75	64	256	21.57	33.72
	12	1,088	16	12.50	33.80	60,912	2,080	15.67	33.75	4,320	256	33.79	896	1,024	21.76	33.76
	19	272	00	12.22	33.77	1,152	864	16.95	33.73	6,048	320	33.84	9,856	768	21.57	33.74
	26	432	48	12.61	33.77	1,808	2,528	16.95	33.78	4,102	768	33.90	12,896	736	22.01	33.84
9	—2	416	00	13.78	33.66	2,960	5,664	16.11	33.74	5,344	448	33.74	12,232	544	21.01	33.75
	9	112	00	14.61	33.58	928	1,888	17.00	33.80			33.74	18,928	704	20.70	33.71
	16	240	16	13.05	33.66	1,280	1,504	16.44	33.74				14,848	1,012	21.23	33.76
	23				33.42	544	400	16.56	33.88	1,760	544	33.73	7,744	1,496	20.19	33.77
10	—7	32	16	14.89	33.38	3,408	2,688	14.83	33.85	6,368	416	33.67	4,434	1,056	19.34	33.74
	14	320	32	14.67	33.46	14,528	2,368	16.00	33.89	40,608	768	33.69	2,336	288	19.26	33.75
	21	592	00	13.11	33.50	320	448	15.56	33.93				572	572	18.36	33.74
	28	288	48	13.11	33.49	32	1,600	16.83	33.93				3,504	528	18.39	33.73
11	—4	16	00	13.44	33.30	128	320	17.78	34.13	960	544	33.74	220	484	18.44	33.81
	11	00	16	12.17	33.34	32	176	17.36	34.07	1,120	192	33.68	1,298	440	17.81	33.83
	18	00	32	12.83	33.38	208	176	17.22	34.12	1,888	832	33.71	3,036	1,034	17.04	33.82
	25	32	16	13.44	33.37	192	80	17.22	34.26	1,952	2,176	33.70	330	5,874	17.23	33.79
12	—2	48	00	13.22	33.53	64	96	17.78	34.06	256	1,056	33.77	924	5,313	17.29	33.75
	9	96	16	12.83	33.58	16	144	17.78	34.12	96	512	33.79	66	4,950	17.11	33.69
	16	64	00	12.50	33.61	32	464	16.11	34.06	160	32	33.77	110	5,038	16.98	33.73
	23	00	32	11.44	33.57	240	1,376	14.44	34.00	64	64	33.69	484	418	13.57	33.58
	30				33.50	6,736	2,384	13.89	33.91	960	736	33.69	44,354	1,936	14.51	33.65
					33.51	1,024	416	14.44	34.00	8,704	672	33.08	61,336	1,584	14.95	33.67

QUANTITATIVE DISTRIBUTION

AT DIFFERENT PERIODS OF THE YEAR

At *Pacific Grove*, the numbers of diatoms per liter were of the same order of magnitude in so far as records are complete, at two periods during the year; from the week ending March 4 through the week ending April 1, and from the week ending July 1 through August 12 (table 1 and fig. 1). During the first period, the lowest average weekly production was for the week ending March 4 (1,040 cells per liter), and the highest average weekly production was for the week ending March 11 (6,084 cells per liter). Quantity productions from January 1 through the week ending February 25 and from the week ending August 19 through the week ending October 21 were much alike. The range in weekly averages for the first period was from 64 cells per liter, weeks ending February 4 and 18, to 704 cells per liter, week ending January 14. The period for the week ending October 28 through December 16 showed the lowest production of the year, the weekly averages varying from 0 to 94 cells per liter (table 1 and fig. 1).

The weekly averages of the numbers of dinoflagellates were too small to have any significance (table 1 and fig. 2). For this reason they are not considered in the discussion.

At *Point Hueneme* pier the weekly averages of diatoms per liter were irregularly variable, especially from January 1 through the week ending October 7, and, although there were definite periods of maximum productivity, some high weekly averages were followed by relatively low ones (table 1 and fig. 1). The period from the week ending May 6 through the week ending June 24 probably should be considered as the period of highest pulse, although the averages for the weeks ending May 20 and 27 were below 100,000 cells per liter (table 1 and fig. 1). Other weekly averages during this period were higher than this number. The average for the week ending May 6 was the highest of the year for this pier (398,768 cells per liter). During the period from the week ending July 1 through the week ending August 12, production was high (table 1 and fig. 1). Indeed, the two aforementioned periods may be considered as one extended pulse if, in addition to those mentioned above, we disregard such relatively low weekly averages as these: week ending July 1, 25,664 cells per liter; week ending July 15, 1,600 cells per liter; and the averages of the next two weeks, both of which were less than

100,000 cells per liter (table 1 and fig. 1). The consecutive weekly averages for the period from January 1 through the week ending April 29 are still more variable: 272 to 320,193 cells per liter (table 1). Production for the last part of the year was relatively low, and the range of variability was also pronounced: from 32 cells per liter, weeks ending October 21 and November 4, to 14,528 cells per liter, week ending October 7 (table 1).

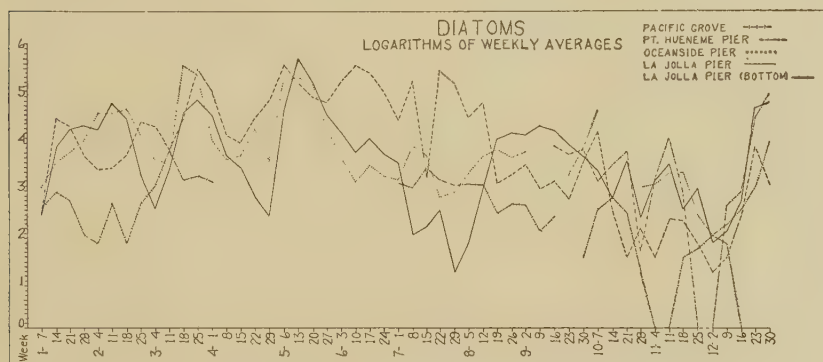


Fig. 1. Graph of logarithms of weekly averages of diatoms per liter at Pacific Grove and Point Hueneme, Oceanside, and La Jolla piers, 1923.

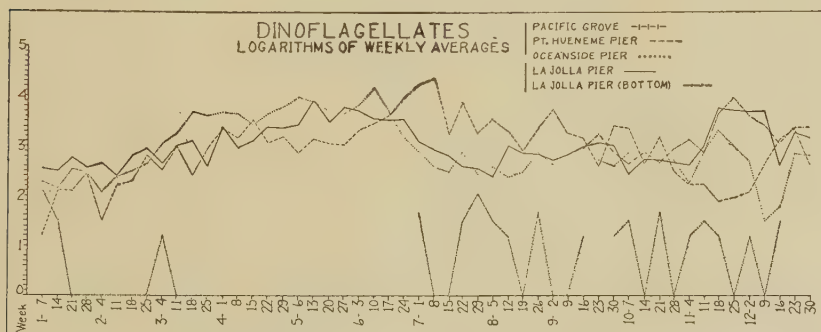


Fig. 2. Graph of logarithms of weekly averages of dinoflagellates per liter at Pacific Grove and Point Hueneme, Oceanside, and La Jolla piers, 1923.

The highest production of dinoflagellates during a period, which may constitute a pulse, was from the week ending June 3 through the week ending July 22. Or, it may be considered that the duration of the pulse was shorter: from the week ending June 24 through the week ending July 8 (table 1 and fig. 2). The highest weekly average for either period was for the week ending July 8 (24,320 cells per liter). Indeed, the most apparent feature of the weekly averages during the entire year is that, with six exceptions, they were of the same order of magnitude from the week ending April 1 through the

week ending October 21 (table 1); i.e., all except six weekly averages for this period were of more than 1,000 and less than 10,000 cells per liter. The first twelve weekly averages varied from 16 to 896 cells per liter. The averages for the last ten weeks were relatively low, with the exception of those for the weeks ending December 16 and 23 (table 1 and fig. 2).

At *Oceanside* pier, two periods of two and three weeks, from the week ending March 18 through the week ending March 25 and from the week ending May 6 through the week ending May 20, should be regarded as the periods of highest pulses of diatoms (table 1 and fig. 1). The weekly averages of the periods preceding and following did not nearly approach those of the intervening periods. Moreover, these periods were outstanding in productivity for the entire year (see table 1). The highest single weekly average was during the first-mentioned period, 380,281 cells per liter for the week ending March 18. Weekly averages preceding the first pulse were variable, but for the period from the week ending February 4 through the week ending February 18, weekly averages were almost the same (table 1). Weekly averages were not consistent in size for any one period after May 20, varying from 96 to 40,608 cells per liter, for the weeks ending December 2 and October 7, respectively (table 1).

The weekly averages of dinoflagellates fall into four groups. The first group, from January 1 through the week ending February 25, are all of the same order of magnitude: from 140 to 448 cells per liter. The second group extends from the week ending March 4 through the week ending July 1. With one exception, the averages of this group are of the same order of magnitude: the catch for the week ending June 10 was 14,752 cells per liter, while all others for this period were above 1,000 and below 10,000 cells per liter (table 1). The latter half of this period should be considered as that of highest pulse for the year. The weekly averages for the period from the week ending July 8 through the week ending November 11 fall into a group similar to the first period mentioned above: they range from 288 to 864 cells per liter. The averages for the remainder of the year, which constitute the fourth group, are variable, ranging from 32 to 2,176 cells per liter (table 1 and fig. 2).

At *La Jolla* pier, the period of highest pulse of diatoms was from the week ending May 6 through the week ending June 3 (table 1 and fig. 1). Two of these weekly averages really constituted the highest productivity of the year, even if as many as ten other consecutive weeks are considered as a whole; one of these averages (525,120 cells per liter) was the largest number of diatoms counted for one week at any one of the four stations. Weekly averages for the period from

the week ending January 21 through the week ending February 18 were of relatively the same range (15,232 to 57,904 cells per liter) as were those from the week ending March 18 through the week ending April 1 (table 1 and fig. 1). The latter analysis also applies to the four weeks extending from the week ending August 26 through the week ending September 16. Weekly averages for the last two weeks of the year were relatively high.

Weekly averages of dinoflagellates for first nine weeks of the year were of the same order of magnitude: from 320 to 896 cells per liter (table 1). Maximum production came from the week ending April 15 through the week ending July 1, the middle of this period being that of highest pulse of the year (table 1 and fig. 2). Seven of the last eight weekly averages of the year range from 1,034 to 5,313 cells per liter.

COMPARATIVE NUMBERS

A study of the quantitative distribution of diatoms and dinoflagellates at the four stations throughout the year emphasized the fact that these organisms were not so abundant at Pacific Grove as they were at any one of the other three stations. The fact that collections there were made nearer to shore than at the other stations may account for some of the differences. Lack of collections during some of the periods which were productive at other stations also may contribute to the poor showing. Whatever the explanation may be, Point Hueneme, Oceanside, and La Jolla piers are the only stations in this series that offer similarities in quantitative distribution (table 1, and figs. 1 and 2).

A comparison of the totals of the weekly averages of these three pier stations for the entire year, using only the averages of five or more digits in the case of diatoms and the averages of four or more digits in the case of dinoflagellates, indicates that these three stations produced as follows:

	Point Hueneme	Oceanside	La Jolla
Diatoms	3,071,058	1,337,178	1,189,864
Dinoflagellates	114,302	94,959	79,125

Thus, the employment of only the highest weekly averages indicates that Point Hueneme pier ranked first in production; Oceanside pier, second; and La Jolla pier, third. This is true with regard to both organisms. The addition of the lowest weekly averages to the above figures does not change the order, neither does it appreciably change the magnitude of the differences (table 1).

A comparison among the periods during which pulses occurred at these three stations shows some similarities and some differences

in time of year and extent of duration. Some of these relations have been pointed out, but comparisons not made, in the preceding section. They are more readily apparent from a study of figures 1 and 2 than is possible from a study of the discussion in the text.

GENERA AND SPECIES

On account of the mass of material, it is impracticable to give in the text or in tabular form details of count records, which show the distribution of all genera and species at all stations. Consequently, it is necessary to choose an arbitrary means of treating this subject, and present only the data which indicate the diatoms and dinoflagellates of the largest numbers and highest frequencies in the weekly averages of the three representative stations, Point Hueneme,

TABLE 2

FREQUENCY OF OCCURRENCE OF IMPORTANT GENERA AND SPECIES OF DIATOMS AT THREE STATIONS IN NUMBERS OF WEEKS PER YEAR

Species	Point Hueneme Pier	Oceanside Pier	La Jolla Pier
<i>Chaetoceras compressum</i> Laud.....	36	27	29
<i>C. criophilum</i> f. <i>volans</i> (Schütt).....	26	15	18
<i>C. difficile</i> Cl.....	30	9	17
<i>Chaetoceras</i> sp.....	41	37	43
<i>Coscinodiscus</i> sp.....	49	24	28
<i>Lauderia borealis</i> Gran.....	26	35	26
<i>Nitzschia seriata</i> Cl.....	33	24	29

TABLE 3

DISTRIBUTION OF IMPORTANT GENERA AND SPECIES OF DIATOMS AT THREE STATIONS: 25,000 OR MORE CELLS PER LITER FOR THE WEEKS ENDING AS SHOWN

Species	Point Hueneme Pier	Oceanside Pier	La Jolla Pier
<i>Asterionella japonica</i> Cl.....		3-18; 3-25; 5-6.	
<i>Chaetoceras compressum</i> Laud.....	3-25; 4-1; 5-6; 5-13; 6-10; 7-22; 7-29.	3-18; 3-25; 5-6; 5-13; 5-20.	5-6; 5-13.
<i>C. difficile</i> Cl.....	5-6; 7-22.		5-13.
<i>Chaetoceras</i> sp.....	5-6; 5-13; 6-10; 7-22; 7-29.	3-18; 3-25; 5-6; 5-13; 5-20.	5-13.
<i>Eucampia zodiacus</i> Ehrs.....	5-6; 5-13; 7-8.		
<i>Nitzschia seriata</i> Cl.....	5-6; 5-13; 5-20; 5-27; 6-3; 6-10; 6-17; 6-24.	5-13; 5-20.	5-13; 5-20; 5-27.

Oceanside, and La Jolla piers. For this purpose, all species which occur in one-half or more of the weekly averages of any one or more of the above-mentioned stations have been tabulated to show not only the occurrence at this particular station, but at the other two stations as well (table 2). And, in order to show quantitative distribution of species among the three stations, all diatoms which total 25,000 or more cells per liter in any one or more weekly averages of any one or more stations, are given in table 3. This same procedure has been followed in the case of dinoflagellates, except that 1,000 cells per liter is the lowest number used (tables 4 and 5). This method of treatment enables one to make a comparison of distribution of species among stations.

TABLE 4
FREQUENCIES OF OCCURRENCE OF IMPORTANT GENERA AND SPECIES OF DINO-
FLAGELLATES AT THREE STATIONS IN NUMBERS OF WEEKS PER YEAR

Species	Point Hueneme Pier	Oceanside Pier	La Jolla Pier
<i>Ceratium furca</i> (Ehrg.) Clap. Lachm	40	33	38
<i>C. fusus</i> (Ehrg.) Clap. Lachm.....	14	14	27
<i>C. tripos</i> (O. F. M.) Nitzsch.....	31	19	34
<i>Peridinium depressum</i> Bail.....	31	20	29
<i>P. granii</i> Ostf.....	36	20	21
<i>Peridinium</i> sp.....	34	25	50
<i>Prorocentrum micans</i> Ehrg.....	33	37	34

TABLE 5
DISTRIBUTION OF IMPORTANT GENERA AND SPECIES OF DINOFLAGELLATES AT THREE
STATIONS: 1,000 OR MORE CELLS PER LITER FOR THE
WEEKS ENDING AS SHOWN

Species	Point Hueneme Pier	Oceanside Pier	La Jolla Pier
<i>Ceratium furca</i> (Ehrg.) Clap. Lachm	4-15; 7-8; 9-2.	4-22; 4-29; 5-6; 6-10.	
<i>C. tripos</i> (O. F. M.) Nitzsch.....		6-10.	
<i>Peridinium depressum</i> Bail.....	6-10; 6-17; 6-24; 7-8.	6-10.	
<i>P. granii</i> Ostf.....		5-6.	5-13; 6-24.
<i>Peridinium</i> sp.....	7-22; 9-2; 12-16.	5-13; 11-18.	
<i>Prorocentrum micans</i> Ehrg.....	6-24; 7-1; 7-8; 7-22; 8-5; 9-2; 9-30; 10-7; 10-21.	3-18; 3-25; 4-1; 4-8; 4-15; 4-22; 4-29; 5-6; 5-13; 5-20; 5-27; 6-3; 6-10; 6-17.	4-1; 4-22; 5-6; 5-13; 5-20; 5-27; 6-3; 6-10; 6-17; 11-18; 11-25, 12-2; 12-9; 12-23.

TEMPERATURE AND SALINITY

A consideration of the influence of these two physical factors on the production of diatoms and dinoflagellates may lead to varied opinions and conclusions. A study of table 1 and figs. 3 and 4 will show that in some weeks of the year there seemed to be a given relation between these two factors and large weekly averages; in other weeks of the year, the reverse was true. It is well known that, where more than one factor influences a given condition, the influence of one of these factors cannot be ascertained accurately unless all other factors can be controlled. Such control, of course, is not possible under marine conditions. Therefore, in the consideration of the data presented in this paper, the most feasible method is the comparison of specific cases of these factors and the corresponding production of diatoms.

For the week ending May 13, production of diatoms at the La Jolla pier reached the maximum for a period of similar length during the year, and production at Point Hueneme and Oceanside piers was relatively high (table 1 and fig. 1). Inspection of table 1 and figure 3 shows that the temperature was highest at Oceanside, less than a degree lower at La Jolla, and more than four degrees lower at Point Hueneme. From these data, then, it would seem that relatively high temperatures at Oceanside and La Jolla are factors in abundant production. The salinities were as follows: La Jolla, 33.53; Oceanside, 33.65; and Point Hueneme, 33.86. The difference between any two of these figures is significant, this assertion being based on thousands of salinity determinations. From these data, then, it would seem that a relatively low salinity was one of the factors in abundant productions. These comparisons are not unreasonable, for they are based on data obtained during the same week of the year, by the same methods, but, of course, at different stations.

Is it always true that the higher the temperature the higher the production of diatoms? And, is it likewise true that the lower the salinity, the higher the production of diatoms?

Consideration of other weekly averages taken from the three piers will answer partly these questions. For the week ending June 17, production of diatoms at Point Hueneme pier was relatively high, while at Oceanside and La Jolla piers it was so low that it cannot be compared with production at Point Hueneme (table 1 and fig. 1). Production at La Jolla pier was almost three times that at Oceanside pier. There was only .1 degree difference in temperature between La Jolla and Oceanside, but at La Jolla the temperature was almost

five degrees higher than at Point Hueneme. In this case, then, a low temperature seemed to be one of the factors in high production of diatoms. The salinities for the three piers during the same week were: Point Hueneme, 33.77; Oceanside, 33.74; and La Jolla, 33.75.

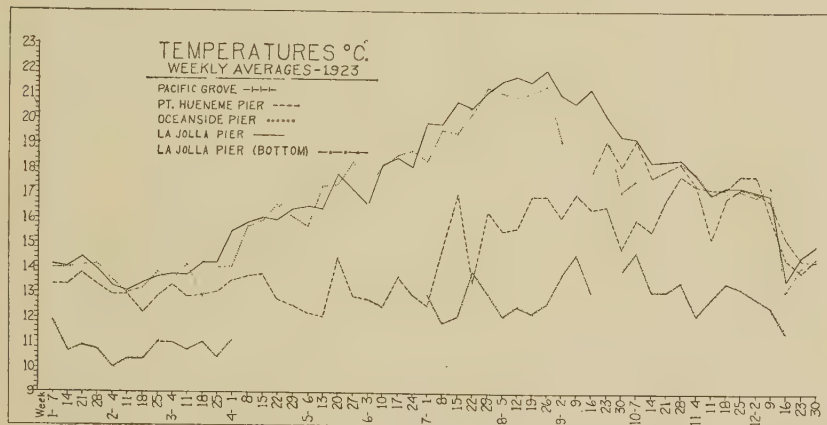


Fig. 3. Graph of weekly averages of temperatures in degrees C. at Pacific Grove, Point Hueneme, Oceanside, and La Jolla piers, 1923.

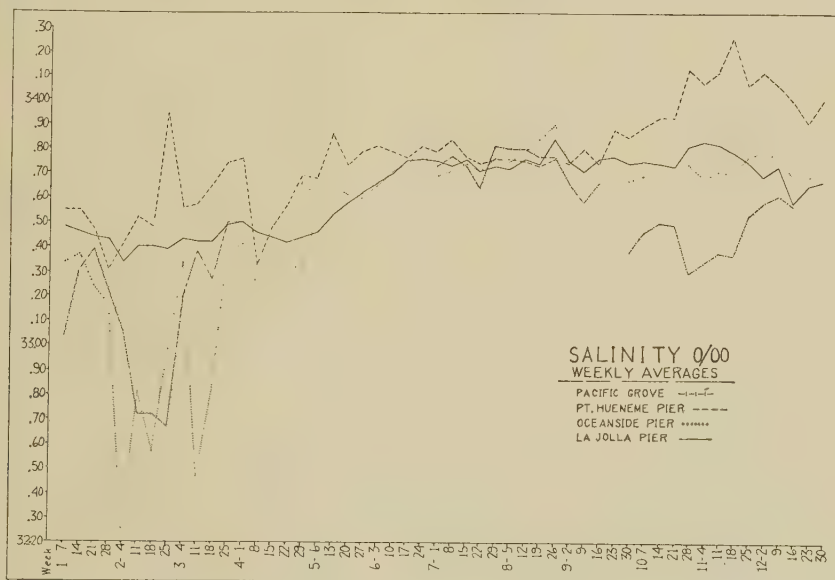


Fig. 4. Graph of weekly averages of salinities in grams ‰ at Pacific Grove and Point Hueneme, Oceanside, and La Jolla piers, 1923.

The difference between any two of these figures is not large and probably would not be considered of significance. Be that as it may, the highest salinity in this case was coincident with the highest production of diatoms.

The relations between temperature and high production and the relation between salinity and high production were high temperature and low salinity in the one and low temperature and high salinity in the cases cited above. Other comparisons, using data collected either in periods of high or low productivity, suggested sometimes the same and sometimes different inferences. This fact indicates that no general statement can be made at this time concerning the influence of these factors.

LA JOLLA: BOTTOM CATCHES

The bottom catches, made at the La Jolla pier with the Kofoid bucket during the last sixteen weeks of the year, afford an opportunity for comparison between the kind and quantity of diatoms and dinoflagellates taken at the bottom and at the surface at the same pier (tables 1 and 6). These catches were made at the same hour as the surface catches.

The total numbers of the sixteen weekly averages for the surface and the bottom were as follows:

	Surface	Bottom
Diatoms	145,590	159,192
Dinoflagellates	32,023	35,290

Production for this period was therefore higher at the bottom than at the surface, but the differences between the figures are not large.

A survey of the species at the surface and at the bottom showed that there was a greater variety of both diatoms and dinoflagellates at the bottom than at the surface, but the differences in this case also were slight. Three species of diatoms were found at the surface, but not at the bottom: *Chaetoceras pelagicum* Cleve, *Rhizosolenia alata* Btw., and *Triceratium* sp. On the other hand, five species were found at the bottom, but not at the surface: *Actinoptychus undulatus* (Bail.), *Asteromphalus hookeri* Ehrs., *Bacteriastrum varians* Lauder, *Dactyliosolen antarcticus* Castr., and *Rhizosolenia semispina* Hensen. None of these species were prominent during this period. All species of dinoflagellates found at the surface also were found at the bottom, but *Dinophysis rotundata* Clap. Lachm. was present at the bottom, during seven of the sixteen weeks, but during none at the surface.

In order to show quantitative distribution of species at the surface and at the bottom, all diatoms which total 10,000 or more cells per liter in any one or more of the weekly averages at either or both levels

are given below in table 7. This same procedure has been followed for dinoflagellates, except that 500 cells per liter is the lowest weekly average considered.

TABLE 6
WEEKLY AVERAGES OF DIATOMS AND DINOFLAGELLATES IN NUMBERS PER LITER
AND TEMPERATURES IN DEGREES C. AT LA JOLLA (BOTTOM),
LAST SIXTEEN WEEKS, 1923

La Jolla Pier (Bottom)				
Week ending		Diatoms	Dinoflagellates	Temp. in °C.
9	-16	7,128	924	17.83
	23	4,752	1,760	19.18
	30	5,896	792	18.17
10	-7	1,276	440	19.20
	14	2,904	792	17.72
	21	5,412	484	18.00
	28	44	924	18.31
11	-4	1,364	1,320	17.48
	11	10,120	792	15.25
	18	748	4,576	16.90
	25	000	9,338	17.23
12	-2	000	4,128	17.10
	9	396	2,816	16.80
	16	748	1,144	15.25
	23	28,204	2,508	14.40
	30	90,200	2,552	14.36

TABLE 7
DISTRIBUTION OF IMPORTANT SPECIES OF DIATOMS AND DINOFLAGELLATES AT THE
SURFACE AND AT THE BOTTOM AT LA JOLLA PIER FOR THE
WEEKS ENDING AS SHOWN

Diatoms	Surface	Bottom	Dinoflagellates	Surface	Bottom
<i>Chaetoceras compressum</i> Laud.....	12-30	12-30	<i>Dinophysis caudata</i> Kent.....	9-23; 11-18; 11-25.	11-4; 11-25.
<i>C. difficile</i> Cl.....	12-30				
<i>C. sociale</i> Laud.....		12-30	<i>Peridinium crassipes</i> Kofoid.....	12-30.	9-23.
<i>Chaetoceras</i> sp.....	9-16		<i>Peridinium</i> sp.....	11-18; 11-25; 12-2; 12-9; 12-23; 12-30.	9-23; 9-30; 11-11; 11-18; 11-25; 12-2; 12-9; 12-16; 12-23; 12-30.

SUMMARY

1. Surface collections of diatoms and dinoflagellates made throughout the year 1923 (exceptions noted in text and in table) at four stations along the coast of California have been studied. These stations were at Hopkins Marine Laboratory at Pacific Grove, and Point Hueneme, Oceanside, and La Jolla piers. Bottom collections made at La Jolla pier during the last sixteen weeks of the year have also been studied.

2. Quantitative distribution of diatoms and dinoflagellates at the four stations throughout the year indicates that the totals of all weekly averages at each station, from the highest to the lowest, were in this order: Point Hueneme, Oceanside, and La Jolla piers, and Pacific Grove.

3. Production at Pacific Grove was so much lower than at any one of the other three stations, that a comparison with production at any other one station is not representative.

4. The periods of highest production of diatoms and dinoflagellates at the three pier stations are as follows:

	Week ending	through	Week ending
Point Hueneme.....	May 6		June 24
	June 3		July 22
Oceanside.....	May 6		May 20
	May 6		June 17
La Jolla.....	May 6		June 3
	April 15		July 1

5. Frequencies of occurrence of the important genera and species of diatoms and dinoflagellates at the three pier stations have been tabulated. Distribution of a given important species among the three stations varied in frequency of occurrence, though in a few cases the differences among the frequencies were small.

6. Quantitative distribution of the important species of diatoms and dinoflagellates among the three pier stations has been tabulated. Considering a given species, four of the seven important diatoms occurred at least once in numbers of 25,000 or more cells per liter in the weekly averages of each of the three pier stations. This was true of five out of six of the important species of dinoflagellates.

7. Upon the data presented in this paper, no general statement can be made concerning the influence of temperature and salinity on

the quantitative production of diatoms and dinoflagellates. In some cases a high temperature and a low salinity were coincident with a high production; in others, the reverse was true.

8. Quantitative distribution of diatoms and dinoflagellates and the variety of species of both organisms were slightly greater during the last sixteen weeks of the year at the bottom than at the surface level at La Jolla pier.

9. Distribution of important species of diatoms and dinoflagellates between the two levels at La Jolla pier during the last sixteen weeks of the year was almost the same.

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PELAGIC FISH EGGS OFF LA JOLLA,
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BY
P. S. BARNHART

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PELAGIC FISH EGGS OFF LA JOLLA, CALIFORNIA

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The following is a brief account of an investigation of certain pelagic fish eggs during the spring and summer of 1926.

During the spring and summer, eggs of fishes form a large part of the contents of the surface plankton caught by the net hauls which are made as a part of the routine work for the investigators at the Scripps Institution. The identification of the species represented by these eggs has long been a contemplated problem. Because of the limited time I decided to concentrate on three or four of the more common market fishes at this season of the year. A constant weekly watch was therefore kept upon the spawning condition of the barracuda, *Sphyraena argentea*, the bonito, *Sarda chilensis*, the mackerel, *Scomber japonicus*, and the yellow-tail, *Seriola dorsalis*.

From the latter part of May to June 15 the gradual enlargement of the ovaries of these fishes was noted. On June 15 I found one *Seriola* out of about 500, one *Sphyraena* out of 340, and one *Sarda* out of 82, with ripe ova. By June 20 nearly all of the two last named fishes brought into the market were in spawning condition. Practically all of these were being taken just off the La Jolla kelp beds. Samples of the ripe ova were taken and a careful microscopic examination made to determine their general characteristics.

On June 30, with our small motor boat and a No. 00 net, I made several surface hauls among the fishing boats along the edge of the kelp beds where *Sphyraena* and *Sarda* were being taken in large quantities. Eggs were procured in abundance and proved to be of two kinds which checked with the characteristics of the ripe eggs of these fishes.

The eggs were separated and placed in glass dishes containing fresh sea water taken from the end of the Scripps Institution pier. The following day many of each had hatched. Descriptions of the ova and hatched larvae of these two species are as follows:

Sphyraena argentea.—Egg transparent; diameter, 1.02 mm.; one oil globule, brownish, .20 mm. in diameter; zona radiata finely striated, covered with fine dots; yolk homogeneous. Perivitelline space small

if any; embryo almost completely in contact with inner surface of envelope. The embryo carries a large globular yolk-sac; total length, 2.25 mm.; length, snout to anus, 1.50 mm.; anus, one-third the distance from posterior edge of yolk-sac to end of caudal fin. Pigmenta-

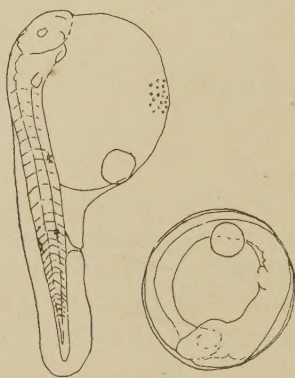


Fig. 1

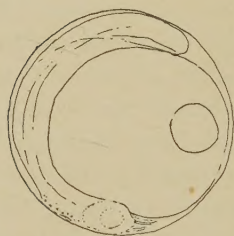


Fig. 2

Fig. 1. *Sphyraena argentea*, egg and larva.Fig. 2. *Sarda chilensis*, egg and larva.

tion very scarce; two yellowish chromatophores, one just above anus, and above it a larger one on the dorsal surface.

Sarda chilensis.—Egg transparent; diameter 1.50 mm.; one yellowish-brown oil globule, .28 mm. in diameter; zona radiata with fine wavy striations; yolk homogeneous. Perivitelline space small, embryo almost completely in contact with inner surface of envelope. The hatched larva 3.75 mm. long; oval yolk-sac; anus immediately behind yolk-sac; chromatophores few, lemon yellow, two on upper edge of dorsal fin, three on ventral fin.

